

Report of the South Pole Power Tiger Team August 11, 2006

1. The Tiger-Team, Charge, Overview of Report

1.1 Participants:

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1.2 Charge to Committee:

The Tiger Team was convened to address the near term challenge facing South Pole electrical power generation: specifically the demand for electrical power exceeds the current generation capability of the new power plant (NPP) as well as the winter fuel storage supply.

The current situation and projections for 2007 and beyond are characterized in the USAP report entitled "2006 Report on South Pole Energy Issues and Recommendations," dated June 23, 2006, and hereafter referred to as the Armstrong report.

The immediate concern of the Tiger Team is to determine power options that will allow the South Pole science projects to operate, while maintaining a safe and operational station. The options implemented should be viable until such time that the long term plan for South Pole power is developed and implemented.

Implementing many of the power options in time for the 2007 season will require immediate action. Furthermore, the plan for South Pole power is needed to decide if the South Pole Telescope will be deployed. This decision is required by August 15, 2006.

The Charge to the Tiger Team is taken from the July 5-6, 2006 O'Hare NSF/RPCS/ICECUBE/SPT meeting report, and endorsed here by PRSS Section Head Erick Chiang:

1. Verify power requirements for winter 2007 using Armstrong report as basis and revalidate if needed.
2. Achieving 660 kW - 700 kW average 2007 winter use. Develop options and identify associated challenges: conservation, power shedding and power management.
3. Generating more power. Develop options and identify associated challenges: additional power generation, required fuel storage and cargo demands.
4. Contingency planning. Procedures if the fuel tanks are not left full at end of the season.

1.3 Team activities and overview of the report:

The Committee met by teleconference on July 18, 19, 21 and 26, 2006. The power issues were discussed at SCOARA telecons on July 11, 17 and 24, as well as in SCOARA Cryogen working group telecons on July 17 and 21. Input was also provided by the current winter-over science crews at the South. A complete first draft of the report was circulated July 27. Further committee discussions and report iterations proceeded by email and individual phone calls.

Notes and agenda from the tiger team telecons and documents used by the Tiger Team are posted on the SCOARA web site: <http://astro.uchicago.edu/scoara>

The bulk of the report is divided into two main sections: Section 2 deals with power projections and conservations measures and provides the required average power generation required to meet science goals in winter 2007 while maintaining a safe and operational station. Section 3 deals with options for generating the required power. Peeking into the future, we provide a brief look toward 2008 and beyond (Section 4).

The team gives ten specific recommendations in the report, highlighted in boldface italic print. We believe that following these recommendations will lead to sufficient average 2007 winter power generation to conduct the science goals while maintaining a safe and viable operating station.

2. Power projections and conservation measures

2.1 Revisiting the Armstrong report's 2007 winter power projections

We followed two methods for projecting 2007 winter power requirements:

1. Computing the incremental power requirements to the current 2006 winter usage. This method should have minimum uncertainty, but it does not provide an understanding of the complete power budget. The current average power usage has been about 580 kW.
2. Line by line validation of 2007 winter projections from Armstrong report, with care to identify possible savings.

In the table below we identify projected increments to the current 2006 average usage as well as savings to the 2007 winter projected usage. Note that the increments and savings are usually different (see comments in table).

Table 1. Revised average power projections for winter 2007

Revisiting power projections for 2007 average winter use.		
INCREMENT (kVa)	SAVING (kVa)	Comments
0.0	20.0	Logistics Facility line 14; this could be delayed
39.0	0.0	Rod Well development - deemed to be essential for 2007
0.0	4.8	Elevated siding, line 34, should not be in 2007 projection
0.0	15.0	ICECUBE DNF double counted in 2007 projection
0.0	2.0	Update to MAPO usage
(13.3)	13.3	Replace chillers on helium re-liquefier compressors with heat exchanger
(12.3)	12.3	Stage running of the 3 liquid helium re-liquefiers (equiv. 2 average)
13.0	(12.0)	Cryofacility building lights etc. (correction to projection)
(12.0)	3.0	Operate the liquid nitrogen plant at 50% duty cycle (note 2007 projections had assumed 15 kVa vs. 24 kVa actual)
(8.3)	8.3	Replace lights with 60 Hz low EMI electronic ballast
81.1	0.0	SPT
22.2	0.0	ICECUBE increase
109.4	66.8	Subtotal
644.4	860.0	Average power from current levels and from Armstrong report for 2007
753.8	793.2	Adjusted 2007 Average Power Projection (kVa)
678.4	713.9	Adjusted 2007 Average Power Projection (kW)

Additional Science Savings		
(10.6)	10.6	AMANDA/SPASE possible permanent cut - see text
(7.8)	7.8	ICECUBE savings 2007 only, required in 2008 - see text
(11.1)	11.1	SPT savings 2007 only, required in 2008 - see text
(29.4)	29.4	Subtotal
724.4	763.8	Minimum 2007 Average Power Projection (kVa)
651.9	687.4	Minimum 2007 Average Power Projection (kW)
717.1	756	Minimum including 10% contingency (kW)

The results shown in Table 1 should be interpreted with caution. It is encouraging that the projections generated by the two methods are in relatively close agreement and that they are not far beyond the reach of the current average winter power generation capabilities. We stress, however, that the incremental projections are appropriate for the middle of the winter, when power loads are low. South Pole power loads are historically higher at the transitional periods at the beginning and end of the winter season. Unless further cuts can be found, we therefore recommend implementing a plan to supply an average 2007 winter power of 760 kW to supply adequate contingency.

Recommendation 1: Implement the power saving measures outlined in the Table 1, including:

- 1. Delaying the Logistics Facility. Note: alternative DNF space found elsewhere for 2007.**
- 2. Replacing lights with 60 Hz electronic ballast units. Requires procurement. Note: EMI impact is being addressed; initial review indicates there is no impact. The 10% reduction in light output found acceptable.**
- 3. Replace chillers used in helium re-liquefiers with outside air heat exchangers. Note: RPSC is now in the process of installing a glycol loop in the new cryogen facility which will replace the chillers.**

2.2 Additional 2007 power savings?

Enumerated below are additional ideas for conserving power that were discussed by the team. Only the first item led to further savings, and is included in the above table.

1. Additional science savings. Can we shut down and/or descope science experiments. Recommendations that involve the ranking of science projects are beyond the charge as well as the constitution of this committee. It is the responsibility of the NSF/OPP Antarctic Science Program. The program manager should be consulted on the science budget and, as for funding budgets, determine how to conduct the best science under this constraint. In addition, the program manager will need to be provided with the full impact of each project on South Pole power, including for example, power associated with personnel on station, cryogen usage, fuel usage for directly providing thermal heat, etc.

By far the largest science power users are ICECUBE/AMANDA, SPT and the Cryofacility support to provide BICEP and QUAD with liquid helium and nitrogen. Each of the remaining projects requires much less power, and so seeking substantial power savings from them would come at a high cost to science. The table above already includes maximum cuts to the Cryofacilities.

Therefore the ICECUBE/AMANDA and SPT projects were asked to identify additional possible power savings for 2007, even at reduced science scope. The results were:

- a. 9.5 kW permanent savings from ICECUBE/AMANDA by shutting down SPASE-II (4 kW) and AMANDA muon-DAQ (5-6 kW). These have been approved by the IceCube project and collaboration. They found that the impact on the science scope is acceptable in order to resolve power issues.
 - b. 7 kW savings only in 2007 winter (17 kW 2007 summer) from ICECUBE
 - c. 10 kW savings only in 2007 winter from SPT.
2. Can we save by phasing projects, i.e., managing power on site? For science this can only be done by doing less science. By phasing things like the sauna or the growth chamber, we cut down peak but not average power.

3. Can we house people in only A1 and put B1 in survival mode? It is not feasible to shut down a pod completely and let it go into deep freeze. Furthermore B1 includes station functions that must be maintained. The team found that the pods were already operating to maximize controllable power conservation. Additional power savings were only identified by decreasing the winter-over population. Note that the 2006 and 2007 projections in the Armstrong report extrapolate from the current power usage of the pods.
4. Are there further power savings in DNF? DNF space is extremely tight if, as recommended, the Logistics Facility is delayed. No further savings were identified. The amount of DNF was also found to be adequate for 2007 with the additional DNF planned to be constructed this summer.
5. Vehicles have engine heaters. Could we trade running engines to save on electrical power? This is a small power load. Furthermore, as we discuss below, the real issue is in fact fuel storage, so this option is not helpful.

Recommendation 2: Implement the science savings identified in Table 1. Note that the ICECUBE and SPT savings only apply for 2007 winter; they are not available in winter 2008 and beyond.

2.3 Required power generation for 2007 winter

Finding no further power savings for 2007 winter, assuming the previous recommendations are implemented, and adding a 10% contingency, we arrive at the following finding and recommendation:

Recommendation 3: A average power of 760 kW is required for winter 2007. This includes a 10% contingency, but does not account for the higher loads expected during the transitional periods at the beginning and end of the winter season. Noting that this power level is beyond the basis of design for the power plant, we recommend that NSF task the South Pole Design Team to develop, evaluate and implement a plan as soon as possible for the plant to deliver 760 kW average power throughout the 2007 winter.

2.3 Contingency power shedding:

What extreme measures would be done if we found the power load to be 50kW to 100kW over at beginning of winter season? What would be cut? How would the power shedding decisions be made?

If such a crisis occurs during the summer, the short term solution is to use external generators. External generators could, in principle, be used in the winter, but this does address fuel usage which is most likely the limiting resource.

External power generation could be pursued in the winter if the power plant was not working properly, i.e., if a problem with the power plant was the issue and not the fuel supply. The added operation and maintenance work associated with an external generator makes this option unattractive for simply increasing the winter power generation capacity. However, contingency plans for external generators for emergency use should be –and in fact are– in place.

Therefore, if such a crisis occurs during the winter, power shedding will be required. Currently, insufficient power monitoring equipment is in place so that an informed decision on what power to shed could be made. This leads to the following recommendation:

Recommendation 4: The implementation of the power monitoring plans should proceed with high priority in the upcoming 2006/07 summer season, and a power shedding contingency plan should be constructed as soon as accurate power load information available.

3. Providing 760 kW average power in winter 2007

3.1 Generating 760 kW

As described in the Armstrong report, the South Pole power plant generates 600 kW continuous load using one of three 750 kW main generators with double firm contingency. When the power demand exceeds 660 kW for more than 10 minutes a 239kW peaking generator is warmed up and brought on line to increase power availability and stability. The current generator set (main plus peaking generator) is expected to achieve its design prime power rating of 989 kW this year, leading to a continuous power rating (conservatively set at 80% of prime) of 791 kW,

It appears, therefore, that there is sufficient power generation capacity to meet demand, as long as there is fuel to run the generators.

Note, however, to meet the recommended 760 kW average load requires running the peaking generator continuously. The peaking generator will need scheduled maintenance, e.g., oil changes and valve adjustment, every 500 and 1000 hours. The maintenance can be done in a 9 hour shift.

During the peaking generator maintenance period, either the power load must be reduced to below 660 kW, or a second main generator must be running. In order to meet double firm contingency with two main generators running, the third main generator must be in stand-by mode, with its maintenance already completed.

The alternative to using the peaking generator to meet the 760 kW average load, is to use an external generator. As discussed above, we feel this is not feasible except for emergency contingency.

Recommendation 5: The 760 kW average 2007 power should be supplied by the existing power plant with the peaking generator running. When the peaking generator is serviced and the power demand exceeds 660 kW, two mains should be run with the third main in standby mode.

We stress that running the peaking generator continuously is not a long term solution. We recommend it as a temporary solution until the long term plan for the South Pole power can be developed and implemented.

3.2 Fuel supply for generating 760 kW average winter load

With the peaking generator running continuously, the challenge of meeting the recommended 760 kW average winter 2007 power becomes one of providing sufficient fuel on the station.

According to the Armstrong report and estimates done by committee members, the winter useable winter fuel supply – assuming it is topped off at the end of the summer season – is sufficient to provide 646 kW average power throughout the winter 2007. This is assuming current generator efficiencies (improvements are underway) and current estimates of fuel required on station to directly provide thermal heat in boilers/furnaces, operated equipment, as well as thermal heat for development of Rod well number three.

To meet the 760 kW average load we therefore should consider:

1. Conserving the amount fuel used for thermal heat so it can be used in the power plant.
2. Increasing the available fuel stored over the winter.
3. Increasing the generation efficiency of the generator set.

Below we list options that address items 1 & 2. Note, however, that steps to improve the fuel efficiency of the generators as outlined in the Armstrong report are underway. We heartily endorse these efforts.

Option 1: Do nothing. We must then live within a 646 kW average load. We would be foolish to follow this option without expecting serious impact on science. The committee strongly recommends against this option.

Option 2: Fixing infiltration and exfiltration issues on new station and MAPO. Currently 55,000 gallons of fuel are burned in boilers/furnaces compared to the 14,000 gallons that was calculated in the basis of design. Finding and fixing heat leaks could therefore save up to 41,000 gallons of fuel, which if used in the power station could provide 91 kW of additional average power. We note that the installation of the heat exchanger on the peaking generator exhaust stack will also provide heat to offset the excess station heat loss. Here we assume 50% of the 41,000 gallons of potential fuel savings could be

achieved during the 2006-2007 summer season, providing fuel to generate an additional 40 kW.

Option 3: Increase the available fuel by lowering the intakes suction tubes on the storage tanks. It is estimated that this would provide approximately an additional 8,000 gallons of fuel, sufficient to generate an additional 18 kW.

Note, implementing options 2 and 3 above is expected to provide 58 kW additional average power (up to 109 kW) for a total of 704 kW average 2007 winter power. Furthermore, these two options increase the efficiency of fuel use at the pole; they are therefore strongly recommended by the committee:

Recommendation 6: The infiltration / exfiltration issues with the station and MAPO should be fixed as best as possible with the goal of reclaiming 50% of current boiler fuel use that is beyond the station design goal. An infrared heatloss study and a survey for potential energy reductions should be performed. The installation of an exhaust stack heat exchanger on the peaking generator will also provide more station heat.

Recommendation 7: The suction intakes on the fuel tanks should be lowered to increase the available fuel on station by approximately 8,000 gallons.

Even with the implementation of the above options, we would still fall short of the 760 kW 2007 winter average power target by 56 kW and so we turn to options to increase the station fuel supply in the following options. They could be in place by winter 2007, but at considerable effort.

Option 4: Deliver the eight fuel-tank sleds used by the traverse. These nominal 3000-gallon tanks could provide an additional 22,800 gallons or storage (95% usable capacity), corresponding to an additional 51 kW average winter power. They weigh about 10,000 lbs each. No traverse is planned in the 2006-2007 season, but that is an option for consideration. Note that the traverse could deliver all eight of the tanks with approximately one-third of their total fuel supply remaining when they are dropped off at South Pole. LC-130 airlift would be required to replenish the remaining two thirds.

Option 5: Bring in two 25,000-gallon fuel bladders. If these were filled to capacity (via LC-130 airlift) they could provide an additional 111 kW average winter power. A single fuel bladder would provide 55kW average winter power. The bladders weigh only about 500 lbs and they have been used for station fuel supply in the past. It is suggested that they be placed in old Bio-Med arch. An attractive alternative to plumbing the bladders into the station power plant fuel supply, is to pump the bladder fuel into the first available empty tanks in the fuel arch as a manual transfer operation. The one time transfers reduce leak risk and eliminate the piping installation costs.

Option 6: Bring in new tanks of the type currently used for surface storage; ten at 5000 gallons and 95% usable capacity provides 102 kW additional average winter power.

In light of the above options, we make the following recommendation to increase the station fuel supply by 25,000 gallons to generate an additional 55 kW average 2007 winter power. We stress that this target is the minimum amount of additional fuel. In light of the considerable uncertainties in achieving all of the conservation measures planned, the committee felt that planning for an increase of 50,000 gallons would be wise, although the likely impact on science and station activities due to the cargo constraints would need to be considered.

Recommendation 8: A plan should be in place to increase the fuel storage on station by at least 25,000 gallons for 2007, providing the possibility to generate an additional 55 kW of average 2007 winter power. The weight of the fuel translates into the equivalent of seven flights. A single fuel bladder appears to offer the most attractive solution as they are light and have been used before, although containment issues must be addressed. Alternatively, a traverse delivering the eight fuel-team sleds with as many full 3000 gallon tanks as possible is attractive as it would save flights.

4.0 Looking to 2008 and beyond

The team has not specifically focused on winter 2008, but we note here a few observations based on the 2007 power projections outlined in this report and the projections in the Armstrong report. For 2008, we can expect increments to the 2007 average power usage of 18 kW from losing the 2007-only SPT and ICECUBE savings, 20 kW from the Logistics Facility, and presumably a decrement of 36 kW from the Rod well, and possibly a decrement if QUaD is turned off (the decrement would be mainly due to lower demands on the Cryofacility). This indicates essential flat overall power usage. This does not, however, include any new science projects or the full use of the station. Science projects are already awaiting approval that will further strain the already maximized power and fuel situation. In anticipation of further power demands, we make the following recommendations:

Recommendation 9: If a fuel bladder is selected to provide the extra 25,000 gallons of fuel storage for 2007, then it is further recommended that the bladder containment system, placement (in Bio-Med arch?), and plumbing be designed to accommodate two 25,000 bladders in case two are needed in the future before the long term station power plan can be developed and implemented. If another type of storage is selected it should include the possibility of expanding to 50,000 gallons total for 2008. Furthermore, if the expected results of the conservation measures in this report are not realized in time for winter 2007, it may be necessary to increment the 2007 fuel storage beyond 25,000 gallons.

Lastly, we again point out that the committee was charged with finding short term solutions for winter 2007. We stress that the running the peaking generator continuously is not a long term solution; it is recommend as a temporary solution until the long term plan for the South Pole power can be developed and implemented. An attractive long term solution to expand the power plant capabilities would be to provide one new 750 kW generator to replace the 239 kW peaking generator, and a second fuel arch with a redundant fuel pumping facility. A second fuel arch would both add fuel capacity and provide backup in the event of a fire or major problem with the existing fuel arch, which is the lifeline of the station. A portion of the station fuel could be delivered via traverse to reduce impact on air cargo. This leads to our final recommendation:

Recommendation 10: We support and encourage the design and installation of a larger power plant and fuel storage facility for South Pole Station.